RDT

Brief

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Comprehensive Shear-Wave Velocity Study in the Poplar Bluff Area, Southeast Missouri

Research Development and Technology

Missouri Department of Transportation

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Summary of Results:

MoDOT requested a comparative analysis of four methods to determine the shear wave velocity of soil: crosshole (CH), multi-channel analysis of surface waves (MASW), seismic cone penetrometer (SCPT), and ultrasonic pulse velocity (UPV). The results of field and laboratory testing and data analysis indicate that the MASW method is the most cost-effective and versatile of the four tool. If the MASW tool is utilized for routine geotechnical site characterization, costs will be decreased and reliability will be increased. Additionally MASW has the flexibility to be useful in areas not easily accessible to the other methodologies listed below.

MASW data are more reliable than either SCPT or UPV data, and only slightly less reliable than CH data. However, the MASW method can guide the CH efforts by providing more appropriate locations for drilling. MASW's other advantages make it a superior choice over the CH, UPV and SCPT methods. MASW data are much less expensive than CH and UPV data and can normally be acquired in areas inaccessible to drill rigs. MASW data are less expensive than SCPT data and can normally be acquired in areas inaccessible to SCPT rigs, for example on paved roadway, within bedrock and dense or rocky soil, and on steeply dipping slopes. One other real advantage the MASW method has over the CH, UPV and SCPT methods is that it can be used to map variable depth to bedrock.

Study Purpose:

MoDOT wanted to evaluate the relative utility and cost-effectiveness of four technologies to determine the shear-wave velocity of soils. Three of these technologies are field methods; the fourth is a laboratory method (Table 1). These methods were employed and evaluated at several sites in the vicinity of Poplar Bluff, Missouri as indicated on Figure 1.

Field methods (Figures 2 and 3):

- Cross-hole seismic (CH)
- Multi-channel analysis of surface waves (MASW)
- Seismic cone penetrometer (SCPT)

Laboratory method

- Ultrasonic pulse velocity (UPV)

For comparison purposes, MASW data were acquired at 40 test sites in the Poplar Bluff area (Figure 1). SCPT data were acquired at 20 of these test sites; CH data were acquired at 2 of these test sites. UPV tests were performed on soil samples from 4 of the test sites. The four technologies for determining the shear-wave velocities of soils were then compared and contrasted in terms of accuracy, reliability, functionality, cost-effectiveness, and overall utility (Table 1).

Specific Study Issues and Results (Table 1):

1. **Issue**: Which of the four methods provides the most accurate and reliable shear-wave velocity data? **Results**: Relative rankings: CH (1), MASW (2), SCPT (3), UPV (4).
2. **Issue**: Which method is most functional in terms of data acquisition? **Results**: Relative rankings: MASW (1), UPV (2), CH (3), SCPT (4).
3. **Issue**: Which method is most functional in terms of data processing? **Results**: Relative rankings: MASW (1), CH (2), UPV (3), SCPT (4).
4. **Issue**: Which method provides the most useful shear-wave velocity data? **Results**: Relative rankings: CH (1), MASW (2), UPV (3), SCPT (4).
5. **Issue**: Which method provides the most useful supplemental information about the subsurface? **Results**: Relative rankings: MASW (1), SCPT (2), UPV (3), CH (4).
6. **Issue**: Which method is the most cost-effective? **Results**: Relative rankings: MASW (1), SCPT (2), UPV (3), CH (4).
7. **Issue**: Which method is of most utility to MoDOT? **Results**: Relative rankings: MASW (1), SCPT (2), UPV (3), CH (4).

Table 1: Rankings of MASW, CH, SCPT and UPV methods.

Considerations	MASW (Multi-Channel Analysis of Surface Waves)	CH (Crosshole Seismic)	SCPT (Seismic Cone Penetrometer)	UPV (Ultrasonic Pulse Velocity)
Accuracy and reliability	2	1	3	4
Functionality (acquisition)	1	3	4	2
Functionality (processing)	1	2	4	3
Utility of shear wave data	2	1	3	4
Supplemental considerations	1	4	2	3
Cost-effectiveness	1	4	2	3
Relative utility to MoDOT	1	4	2	3

Conclusions:

CH shear wave velocity data are significantly more reliable than the SCPT data and slightly more reliable than the MASW data. However, the cost of acquiring CH data generally does not justify the expense associated with drilling and casing twinned (or tripled) boreholes down to the base of the zone of interest. We do not recommend the acquisition of CH shear wave velocity data as part of routine geotechnical site investigation work.

UPV shear wave velocity data are comparable to the CH, SCPT and MASW data. Unfortunately, UPV data are expensive to acquire as the laboratory tests are performed on borehole soil samples. We do not recommend the acquisition of UPV data during routine geotechnical site characterization unless soil samples are being collected for other geotechnical laboratory analysis purposes.

SCPT shear wave data are less reliable than either the CH or MASW data. The SCPT tool also suffers from significant operational limitations. For examples, SCPT data cannot normally be acquired in areas inaccessible to drill rigs such as on paved roadway, within bedrock or in dense or rocky soil, and on step slopes. On the upside, the CPT data (acquired simultaneously with SCPT data) can have significant benefit to MoDOT. We recommend that MoDOT acquire SCPT data only when/where CPT control is required.

MASW data are more reliable than either SCPT or UPV data, and only slightly less reliable than CH data. However, the MASW method can guide the CH efforts by providing more appropriate locations for drilling. MASW's other advantages make it a superior choice over the CH, UPV and SCPT methods. MASW data are much less expensive than CH and UPV data and can normally be acquired in areas inaccessible to drill rigs. MASW data are less expensive than SCPT data and can normally be acquired in areas inaccessible to SCPT rigs, for example on paved roadway, within bedrock and dense or rocky soil, and on steeply dipping slopes. One other real advantage the MASW method has over the CH, UPV and SCPT methods is that it can be used to map variable depth to bedrock.

Recommendations:

We recommend that MoDOT employ MASW technology routinely at geotechnical sites where shear wave velocity control and/or information regarding variable depth to bedrock control is required. While MASW control is not a substitute for conventional borings, the tool (when used to supplement conventional borehole data) can reduce costs and/or increase the reliability/utility of the geotechnical site investigation. Improved site characterization should then lead to improved quality, economy and safety of the constructed project.

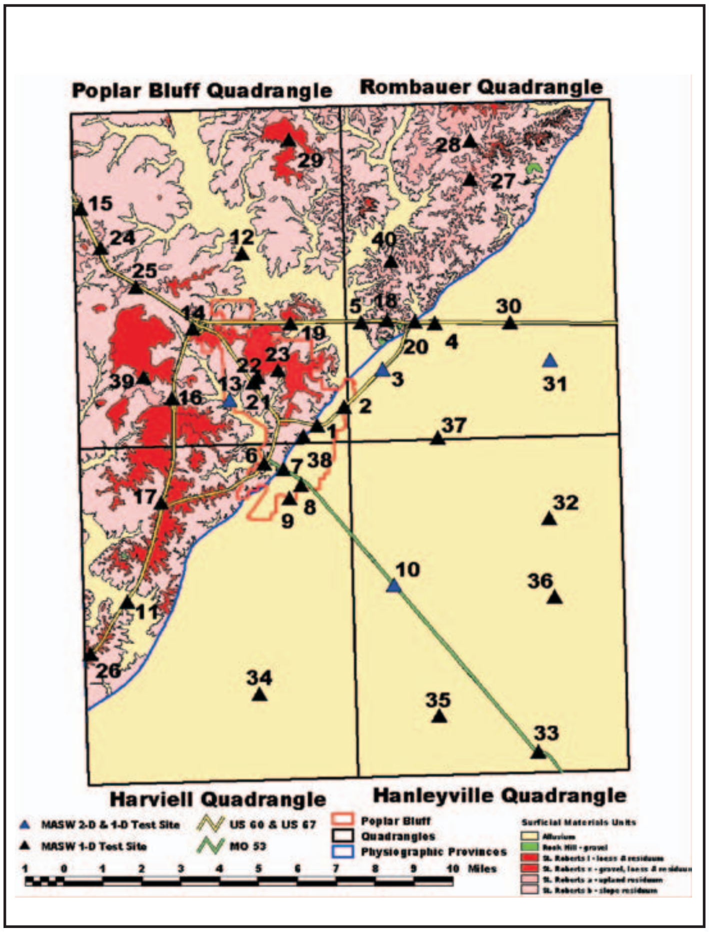

Figure 1: Poplar Bluff study area MASW test sites.

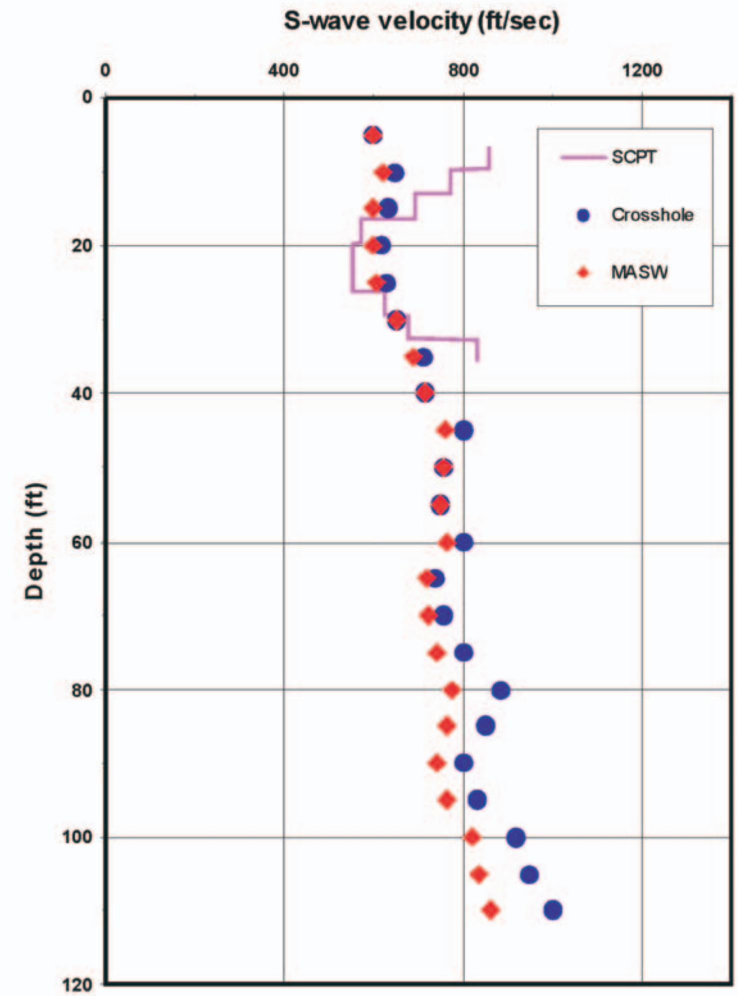

Figure 2: Plot of CH, MASW and SCPT shear wave velocity profiles for MASW Test Site #3 (Figure 1).

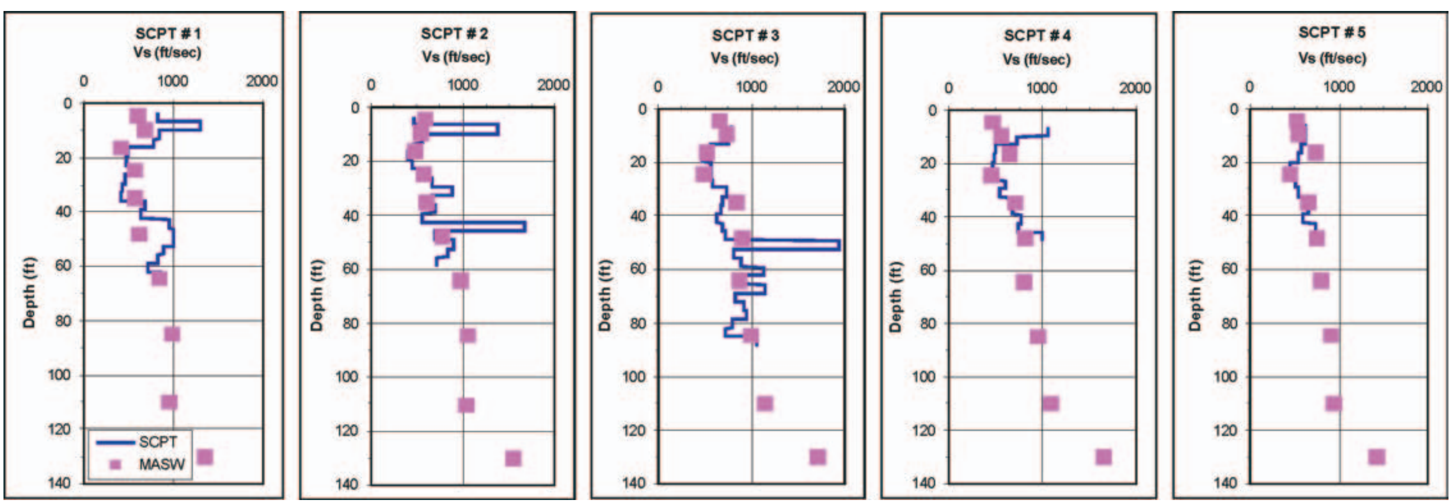

Figure 3: Comparison of SCPT and MASW shear wave velocity profiles from MASW Test Site #10 (Figure

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